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The smelting of lead ores in southwest Missouri

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T H E S I S .

Subject:

THE SMELTING OF LEAD ORES in SOUTHWEST MISSOURI.

By,

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THE SMELTING OF LEAD ORES IN SOUTHWEST MISSOURI.

Occurrence of the ore,

The ores of this district are found mainly in the carboniferous limestone, though there are a few mines in the Cambro-Silurian. The ores of lead of commercial importance, are the sulphide or Galenite, and the carbonate, Cerussite.

Cerussite is found in the regions of the second concentration or the concentration by descending waters. It usually occurs in compact to earthy masses mixed with more or less Galena and Sphalerite and termed locally Dry Bone or Wool Mineral, presumably from its physical appearance. On account of its earthy nature it can not be concentrated to any considerable extent. It is usually carefully treated over hand-jigs, as well as is possible and not have too much of the earthy carbonate washed away. It is then smelted in the blast or slag furnace, which is used in this district and which will be more particularly described farther on. The following assays of Cerussite or "Dry Bone" well illustrate the character of this ore as sold to the Smelter.

Dry Bone or Cerussite,

Lead	59.48 per cent	58.18 per cent
Zinc	5.34 " "	6.41 " "
Water	6.20 " "	like amount.

However Cerussite or Dry Bone is found in relatively small quantities the ore from which practically, all the Pig Lead from this district is produced is Galena or as it is called locally "Mineral", or lead sulphide (PbS). It is very widely distributed over this region occirring as a very soft Galena both in crystallized cubic and Octahedral forms and in desseminated crystalline masses, containing in selected pieces nearly the theoretical lead percentage of 86.61%, however as commonly dressed at the mines and sold to the Smelters it assays from 77% to 80% or even in rare cases 82% lead. It runs under 80% very much oftener than over. This Galenite is remarkably free from silver, copper, antimony, bismuth, cadmium etc. and zinc except as it is physically mixed with Sphalerite. This fortunate freedom from impurities taken into consideration with the small size of any particular deposits has no doubt given rise to the method of smelting, particularly to the general type of furnace used almost altogether in South Western Missouri. The Galena is prepared for market at the mines if occurring in masses by hand cleaning- the clay being knocked from the ore. If occurring in "hard ground" first the free masses are picked out by hand afterward the rest of the ore is either carefully hand jigged or treated over modern steam jiggs.

The following assays of mineral taken from a great many, will give a goodidea of the ore as cleaned and sold at the mines.

Where from	Lead contents	Remarks.
Joplin- - - - - - -	78.62 per cent	80.88%, 81.50%
Oronogo - - - - - -	79.54 " "	Most of this ore runs under this.
Webb City - - - -	78.20 " "	
Aurora - - - - - -	78.00 " "	Contains a good deal of Cerussite.
Springfield - - -	80.73 " "	

The following analyses show the composition of the galena,

Hygroscopic water	0.11%	0.11%	0.14%
Combined water (100 C)	0.41%	0.71%	0.18%
Sand & Silica	1.05%	0.91%	1.20%
Sulphur	13.96%	14.54%	12.36%
Zinc	1.75%	3.25%	5.72%
Lead	81.69%	80.06%	79.51%
Iron	0.36%	0.29%	0.25%
Alumina	0.24%	0.26%	0.24%
Totals	99.56	100.13	99.60

In the deeper mines we find more pyrite or mundic as it is locally termed. This assays a little different that from the ~~Joplin ore~~ Hill Top Mine at Oronogo ~~is~~ runs as follows:

Hill Top Mine.

Lead	81.59%	78.87%
Zinc	1.37%	5.40%
Iron	1.37%	5.12%

As Galena is the ore from which commercially speaking practically all the Pig Lead from southwest Missouri is produced, and as it is smelted in its raw state a knowledge of some of its properties is very essential to the prospective lead smelter. The following are some of these properties.

It is not as fusible as lead, which according to Le Chatelier fuses at 325°C. while galena fuses at 935°C. (Lodin); but when melted it is very fluid and very easily penetrates the fire-brick and fire-brick lining of the furnace often forminga very pretty net work of small veins of ~~small~~ bright crystalline galena. These can be found in the furnace linings or in any small cracks which may have been formed in the castings. I have known it and the lead together to form quite attractive stalactites through cracks in the castings. After melting galena will volatilize without being decomposed if free oxygen is excluded - crystals of this sublimed galena are often found especially when stack furnaces are employed, though they are often found with the hearth furnaces. Galena is a good conductor of electricity. Iron will decompose it better than any other metal. Though copper has a greater affinity for sulphur ~~than~~ it decomposes galena only partially for the reason that the copper alloys so easily with the lead formed and the cuprous sulphide which is formed by this reaction combines with undecomposed sulphide of lead and forms a matte. Zinc decomposes galena partially but the zinc sulphide which forms is so refractory that the lead which is freed can not be separated but forms a black porous mass containing particles of both lead lead and galena. The reaction between Iron and galena may be expressed as follows:

$$PbS + Fe \text{ equals } FeS + Pb$$

This might be termed the general equation for all the metals. The above equation forms the basis for what is termed the iron reduction process. In reality Nolte's formula better expresses the reaction it is,

$$3\,PbS + 3Fe = 2\,Pb + (PbS + Fe_2S + FeS)$$

as the equation expresses the iron sulphide retains some undecomposed galena as is found in practice, though he supposes the existence of a sub sulphide of iron to balance his equation. This reaction has not been used much in southwest Missouri as yet - however I have noticed that in smelting in the ore-hearth some ores which differed practically only in their iron contents, that the ore carryingthe greatest percentage of iron gave the highest yield of Pig Lead. The iron however was present only in small quantities in either case and as yet I have not been able to follow it up and see just the influence the iron has on the smelting process. The probable reason of this will be brought out more fully later on. Both Lime and Baryta decompose galena.With air present metallic lead is formed and both calcium sulphate and sulphide thus,

$$4\ PbS + 4\ CaO = 3\ CaS + CaSO_4 + 4\ Pb$$

which probably represents the case. When the air is excluded the decomposition of the galena is not complete. According to Berthier it is as follows,

$$2\ PbS + CaO + C = Pb + (PbS.CaS) + CO$$

Lead sulphide will dissolve in metallic lead and forms "step-crystals" very often found in furnace accretions.

Preparation of the material (galena) for smelting.

The galena as shipped to the Smelter will assay from 75.00 to 80.00 % even sometimes ~~to~~ 82.00 per cent lead. However the first limits catch most of the galena cleaned at the mines. This cleaned galena is either treated direct in a large "Jumbo" furnace or in an ordinary water-jacketed hearth furnace; or it is rejigged thereby making it as pure as possible and then treated in an American water-jacketed furnace or "Eye". Local surroundings will usually determine which method will be most economical and consequently preferable.in the erection of a smelting plant. The rejigging is not so expensive as one would think costing perhaps not over twelve and a half cents per thousand more than without it. As was stated, for the first method of smelting no preliminary treatment will be necessary. For the second method the ore should be treated as follows. Not considering the storage bins, handling of the material etc. until it is delivered to the crusher it should be taken through a concentration of which the following scheme is typical and will give very satisfactory results. Before proceeding I will state that the ore should never be moved unless unavoidable and as far as economically possible be handled mechanically.

<u>Scheme or plan of concentration system,</u>

The ore or galena is taken as it comes from the mines assaying often from 75 to 82 per cent lead and is rejigged bringing it up to on an average 84 per cent lead. Sometimes it goes up to 85% and a fraction at other times between 83% and 84% lead. The numbers trace the ore on its course through the mill.

1. 10 inch Blake crusher with water to 2.
2. 8 inch bucket elevator to (3)
3. Revolving screene
   (a) through 3/32 holes to(4)
   (b) " 3/8 " "(5)
   (c) " 3/4 " "(6)
   (d) oversize to (1)
4. Three cell jigg, actual jigging surface each cell 13 3/4" by 34".
   1st. cell,
      Headsto(M)
      Hutchwork to(M).
      Tails to 2nd. cell
   2nd. cell,
      Heads (none)
      Hutchwork to (M)
      Tails to 3rd.,cell
   3rd. cell
      Heads (none)
      Hutchwork to (M)
      Tails to (9)
5. Revolving screen
   (a) through 3/16 inch holes to (7)
   (b) oversize to (8)
6. Large one cell rougher jigg,actual jigging surface 17 1/4"by 45 1/2"
   Heads to (M)
   Hutchwork to (M)
   Tails to(18)
7. Two cell jig, actual jigging surface each cell 17 1/2"by 29 3/4"

7. continued (two cell jig)

1st. cell

Heads to (M)

Hutchwork to (M)

Tails to 2nd. cell

2nd. cell

Heads to (M)*

Hutchwork to (M)

Tails to "Zinc tailings"

* When clean enough heads taken off in two places in order to keep blende in as good a condition as possible this removes some pyrite.(at the second one)

8, Two cell jig the same size as No. 7.

1st. cell

Heads to (M)

Hutchwork to (M)

Tails to 2nd. cell

2nd. cell

Heads to (M)* *(see above)

Hutchwork to (M)

Tails to " Zinc tailings".

9. Hydraulic classifier

(a) Heads to (10)

(b) Overflow to (11)

10. Two cell jig, actual jigging surfave each cell 13 5/8" by 33 7/8".

1st. cell

Heads thrown back on the jig until clean enough to go to (M) this will be when enough galena accumulates on the seive to make a good bed.

Hutchwork treated the same as Heads.

Tails to 2nd. cell

2nd. cell

Heads and Hutchwork treated the same as on first cell.

Tails over small settling box to enable blende to settle out

Blende to "Zinc tailings"

Overflow to (16).

11. Hydraulic classifier.

(a) Heads to (12)

(b) Overflow to (13)

12. Two cell jig same size as No. 10.

 1st. cell

  Heads, no heads made

  Hutchwork treated the same as in No. 10.

  Tails to 2nd. cell

 2nd. cell

  Heads, no heads made

  Hutchwork treated the same as in No. 10.

  Tails treated the same as in No. 10.

13. Two cell jig the same size as No. 10.

 1st. cell

  Heads, no heads made

  Hutchwork is treated the same as in No. 10.

  Tails to 2nd. cell

 2nd. cell

  Heads, no heads made

  Hutchwork is treated the same as in No. 10.

  Tails over settling boxes as before

   (to character.
   Settlings to "Zinc tailings" or "Mineral sludge" according

   Overflow to (15)

14. Settling Box, the water drained from the cleaned galena is passed
over this box and the fine ore caught.

15. Settling Box   Heads from 14 to "Mineral sludge".
Overflow " 14 to waste.

  Heads to " Mineral sludge".

  Overflow to (16)

16. Settling box

  Heads to " Mineral sludge

  Overflow to waste

17. Rolls

  The rooled product to (1).

The fine jigs No.s 10, 12 and 13 are operated and the material put according to its composition. The disposition shown above represents the course of the ordinary ore.

The "Zinc tailings" represent the sphalerite in the ore, they carry some lead and some iron. They are sold to the smelter people who give the product a light roast driving off one atom pf the sulphur expressed by the following reaction,

$$FeS_2 + \text{(heat and air) } O_2 = FeS + SO_2$$

After the roast the product is rejigged , taking out as much of the galena as possible and easily separating the sphalerite and iron sulphide from each other. The "Zinc tailings" from the galena jigs usually assay as follows,

<u>Zinc</u> <u>Tailings</u>

Lead	Zinc	Iron	moisture
20.60%	20.90%	8.70%	2 to 3% in shipping condition

and bring from $10 to$15 per ton according to the prices of galena and blende or sphalerite.

The Mineral sludge represents the very fine settling that are carried along with the water whenever itvhas an appreciable motion it contains pyrite, blende galena, cerrusite, smithsonite, calamine etc it assays from 42 to 52 per cent lead and about 9% zinc. In its best condition it will often carry 12% to 15% water. It is smelted in the lead blast or stack furnace.

The cleaned galena is now very pure and for the best sucess of the ore-hearth method of smelting lead ores it is very necessary that this should be the case. If it is desired to get anything like good results in the way of Pig Lead yield. It will usually run from 83.50% to 85.00% lead with a very small percentage of zinc and still smaller of iron. The following analyses show the amounts of impurities to be expected, by R.C.

Insol.	1.72%	0.05%	0.61%	0.12%		0.44%	0.71%	0.53%	0.33%
Lead			84.06	85.84					
Zinc	0.94	1.32	0.94	0.12		0.91	0.73	0.52	trace
Iron	0.24	0.09	0.16	0.05		0.45	0.20	0.20	trace
Antim.	none	none	none	none		none	none	none	none
Silver	1	1	1 1/4	1 1/4	1 3/4	1 1/4	3/4	3/4	3/4 oz per ton
PbS			97.05						
ZnS	1.41		1.41			1.36	1.08	0.77	
FeS_2	0.53		0.34			0.96	0.42	0.42	

The first sample is from oronogo, the ~~from Granby of fine grained structure~~ next three from Granby, the next from Granby of fine grained structure and locally supposed to contain a good deal of silver while carryiny more than the others it is true it did not contain sufficient silver to account for its structure altogether. The next four are from the Joplin district.

The following analyses show the amounts of Antimony, Copper etc present

Where from	Antimony	Copper	Iron	Zinc	Nickel
Granby	Trace	Trace	.05867	.06782	.....
Granby	.00551	.00239	.08602	1.35554	.....
Granby	.02764	.01677	.03220	1.76558	.....
Joplin	.07429	.00478	.02169	.00938	.0660
Joplin	trace	none	.12040	.14679	.....

Taken into consideration with the small extra cost of recleaning the galena and the manifest improvement in the saving of lead in the form of Pig Lead before putting up a smelting plant one should hesitate quite a while before failing to adopt it and be sure his conditions are different from those surrounding others.

Description of Ore-hearths, tools used etc.

There are mainly two classes of ore-hearths employed in this district, known locally as an "Eye" and as a "Jumbo" furnace. Only two of these that represent the highest of their class will be treated

1st. The American water-jacketed ore-hearth or "eye"

2nd. The "Jumbo" ore-hearth, also water-jacketed.

The best type according to my opinion of the American water-jacketed ore-hearth is shown in plate II. While not altogether original it embodies what my experience has taight me is best. It consists of a solid cast lead basin with an extended and sloping apron 23" by 44" in front resting on the two sides and back of this basi n are the water-jackets or "Jams" and thus forming the hearth. These in the bottom of the back carry the three tuyeres. The old forms of this furnace were considerably smaller and carried but one tuyere. The apron laps over the lead pot at the front right hand corner; which is essentially a hollow truncated pyramid hexagonal in shape with an opening near the top for a flue and one opposite and near the the bottom to admit the wood necessary to keep the lead at the proper molding temperature. In tne top of this truncated pyramid is inserted the lead pot proper which is simply a cast bowl 12inches deep and 18 inches across the top with a rim around the top to catch the top of the pyramid. This lead pot as stated is placed under the front right hand corner of the apron under the lower end of a groove in the apron which runs from the center of the back of the apron diagonally nearly to the lower right hand corner and down which the lead flows from the basin.and into the lead pot. Around the front and two sides of this apron is cast a rim to hold the material on the hearth. At the left side of the hearth is placed the slag box, which is simply a sheet iron box kept filled with water from a pipe tapped from the pipe feeding water to the jams or jackets. Into this the slag is thrown and immediately quenched. In front of this and far enough to the side not to be in the smelters way is placed the lime bin about one by three feet. Next to this is the charcoal bin. This is about three feet by four feet. The long dimension perpendicular to the hearth. It is large enough to hold at least 10 bushels of charcoal. Back of the smelters passes a 4 inch air pipe into which two holes are bored in such a manner as to blow on the two men while they are at work, to keep them cool and to assist in keeping the lead fumes away from them. Then along the front of the eye and hood are the bins for receiving the charge to be smelted these are 6 by about three feet and between them and the air pipe mentioned is a passage way of about two feet. These will just hold conveniently the charge of seven thousand pounds. And placed as they are they can be reached easily by the front hand with his charging shovel and still are out of his way. The furnace itself is surrounded with a hood and an eight foot stack to carry off the fumes that occasionally puff out from the front of the ore-hearth. The basin itself is twenty by twenty six inches at the top becoming smaller at the bottom and 14in. deep. It has an eight in ch ring cast aroun the two sides and back of the top which supports the jams. On the in side of this rim is a rectangular vertical projection running around the rim about one inch by one inch. This fits into a corresponding recess cast in the jams and makes the joint between them and serves to hold the jams in place.

The jams or jackets are cast in one piece the castin being 1 1/4 inches thick all around except at the bottom on the inside where it is a little thicker(i,e, 1 1/2 inches), It measures on the inside 26inches wide by 23 inches deep and is 16 inches high in front and 18inches at the back. the jams are 8 inches thick at the bottom and 7 3/4 inches at the top (outside measurements). at the back are three tuyeres dividing the width nearly into four equal parts the distance between either two adjacent tuyeres being six inches. The tuyeres are 1 3/8 inches in diameter though often 1 1/4 and 1 1/2 are used. The longitudinal axes of the t tuyeres prolonged will intersect at the center of the top of the front of the basin. Often when running on some kinds of galena the jams will be tilted forward and sometimes thecbasin will be tilted in the same manner, this pitches the blast down and helps to distribute it through the entire fire. This is always absolutely a condition that must be aimed at if it is desired to obtain the best smelting results. In running fine material this tilting mentioned in often resorted to with good results. The tuyeres are cast as far down to the bottom of the jams as is possible as a very small rise in their position relative to the jams will produce a big difference in the smelting results. The water to cool the jackets or jams enters enters on the left side(looking at the front of the hearth) near the front and bottom circulates around them and leaves on the right side near the front and top. On the back of the jams and at the bottom the air receiver is cast. It comes to within ~~either~~ 7 inches of either side of the jams and extends back 5 inches it extends up 6inches and on the back in cast a thimble 5 inches long for receiving the air pipe. Opposite each tuyere hole in the air box is inserted a plug so as to enable the smelters to punch out the tuyere holes should it become necessary. To this air box the air or blast is lead from the main air pipe which is perhaps 18 inches in diameter and between which and the receiver is placed a sliding valve which is oper ated from the front of the furnace by means od a long wooden lever and enables the front hand to cobtrol his blast. The full blast pressure is 4 ounces used when the furnace is running normally. The water jackets on the inside are the same size at the bottom as at the top. Being made th thicker at the bottom and next the fire to stand the corrosion at this place which, though it is slow and gradual, after a time becomes quite noticable. At the ends and at the back of the sides is placed a good sized plug similar to a boiler man-head so as to enable the jams to be thoroughly cleaned should it become necessary. On the top of the jams rests the rectangular flue made of sheet steel. This flue is usually placed about the center of the sides of the jams and very often extends back of the jams about 4 inches. This is to give an opportunity for small solid particles that have been drawn up with the draft or have popped out of the fire, to settle out. They are collected behind the furnace moistened with water and recharged in the hearth with the Blue Fume. The front of the flue at the bottom is flared out forming a sort of nose, and extending in front of the jams. This flue is extended upward either vertically or sloping backward about eight feet where it is led into a large fume chamber just back of the eyes, here the Blue Fume is caught, which will be described later on.

The tools used etc.

The tools used in smelting with this ore hearth are two long handled smelter's shovels shown in the drawings and one short handled charging shovel. One bar sharpened at the end and similar to an ordinary crow bar. Apaddle shaped spud used to lift the fire etc as described under the method of smelting. A ladle for molding the lead which is simply a part of a hollow sphere 9 inches across the top and 3 inches deep having riveted to it a short pipe handle about 2 feet long in the end of which is stuck a wood handle about 6 ins. long. With the aid of a a leather or belting hand protector for the other hand the man molding is not burned. A small iron rod with a projection at one end formed by bending and flatening it for cleaning out the tuyeres after each days smelting. These tools rest in convenient places when not in use. The spud used by the back hand rests with one end on the right side of the apron and the other on a peg driven in the side of the wall of the hood. The bar used by the front hand rests with one end on the lead pot and caught under the apron. The shovels are kept in easy reach either by hanging hooks or by resting them against pegs driven in the hood wall. Everything is arranged with the idea of making it convenient to the smelter as to enable him to give his whole attention to his fire and keep it in the best smelting condition. The molds are placed just at the right of the back hand who does the molding the other back hand skimming for him. The basin being placed on a brick or concrete foundation all four sides are left exposed and the lead thus kept from getting too hot.

The sketches of the furnace will explain itself without any further description.

2nd. <u>The "Jumbo" ore-hearth</u>,

The other type of furnace used is termed the "Jumbo" furnace, probably on account of its size, and was first used by Mr. Moffet at the Lone Elm smelting plant. He used it in connection with his paint manufacture and as will be seen by the description used it to get the maximum quantity of lead fume by running a fast hot fire with a hot blast. An iron trough 4 feet long and 3 1/2 feet wide and 10 inches deep is divided by a hollow partition along its middle and supported 26 inches above the floor by four legs. Upon each end is a water box 20 inches high by 6 inches wide . the center partition is made 20 inches by two long hollow boxes. the top one carries the blast which is led to the fire through copper tuyeres. These tuyeres pass down through the water box and issue from its side. There are fourteen tuyeres seven on a side. Each tuyere is 1 inch in diameter. As seen by the illustration the furnaces are set back to back with only one large lead basin, thus forming in reality two independent hearths, one on each side. The basin is kept at the same level by an overflow at one corner. The fire floats on this bath of lead and is piled about 10 inches high along the rowxof tuyeres. The hotest part of the fire is consequently surrounded by water jackets. The blast is warmed in the air box. On each side of the apron is fitted an apron as in the eye. This is to retain the charge and on it the particles of slag are picked out. Over the basin the furnace is inclosed in a sheet iron hood 4 1/2 by 5 feet and 11 feet high. This isxconnected to the fume chamber by means of a flue about 15 feet long usually. There is an opening along the front of each fire 15 inches high. The whole furnace rests n a platform 30 inches above the floor , this gives a working space 15 feet by 12 feet

[illegible]

long in front of each fire. The floor slopes toward the hearth and thus enables the charges to be easily brought to the hearths in wheel barrows. There are slag boxes, lime boxes, charcoal or coal boxes with each hearth as with the other ore-hearth just described. The lead overflows into a lead pot 31 inches in diameter and 44 inches deep and is drawn out by a pipe and stop cock and directed into the molds by means of a short piece of movable pipe. These molds are often placed on a truck, holding perhaps twenty pigs and weighed as in the other instance. Sometimes a car is used and ordinarily 30 pigs are loaded on it this making a good load for one man to push around. Mr. Moffet used raw coal of inferior quality the general fuel is charcoal. The fire is worked by two men in eight hour shifts. The prepared galena is dumped on the floor and mixed with 1.5 to 2 per cent of lime before being charged on the fire.

<u>The tools used.</u>

The tools used are vitually the same as with the American water jacketed ore-hearth and no further description is necessary.

<u>The Smelting Process, Method of working etc.</u> (American water jacketed ore-hearth.)

The smelting process or operation in the ore-hearth is mainly a roasting reaction process. It is very similar to that in the reverbratory furnace with the exception that while in the reverb ratory the roasting process is <u>followed</u> by the reaction period at a higher temperature in the ore-hearth both processes go on simultaneously. Carbon and sulphur both acting as reducing agents, besides the action due to the lime. The whole charge floats on a lead bath to enable the the smelters to insert their tools under the charge and thus keep it open and mix it etc. As has already been shown the lead oxide and sulphate as soon as formed by the blast and oxidizing influences present react on the undecomposed galena some lead oxide is reduced by carbon, the lead thus freed trickles down through the charge (which is kept open) into the basin and from this overflows into an outside lead kettle or pot from which it is molded into convenient ~~molds~~ (83 or 84 pounds each) pigs which are trimmed and then ready for shipment. The process more in detail is as follows, The material smelted should conform to the following requirements in order to smelt economically and to produce a good soft pig lead.

There should not be present any considerable amount of silica especially in the presence of cerussite as the silicate of lead begins to form at so lowxa temperature and is so fusible that it renders a fire unworkable if present in quantities. There should not be present any more zinc in any form than can be prevented in any case not over one per cent on the smelting charge. Pyrite helps in the formation of lead sulphate ine the preliminary or first heating and so is an advantage in the roasting - and small quantities tend to keep the charge open by keeping it less fusible during the reaction period. This is the reason no doubt for the beneficial effects of small quantities of pyrite noted in the instances mentioned. Too much pyrite on the charge will react and form double compounds with the lead sulphide thus throwing more lead in the slag. So it is well to keep the pyrite jigged out until further information on the subject is to be had. Limestone or dolomite may be present in small quantities, its influence being advantageous rather than otherwise, still it is well to keep its percentage low as it represents so much inert matter on th charge keeping the galena from being oxidized and preventing contact for the reaction its own chemical effect not being very great. Barite is so much inert matter in the furnace remaining unchanged throughout the process, its occurrence in south west Missouri ores however is rare. Antimony and arsenic while very harmful do not occur in in the galenas of south west Missouri and so do not have to be guarded against. Cerussite or even Anglesite whose occurrence while rare in the ores isxpresent on the charge in the form of burned fume as well as all oxidized lead ores or products assist in smelting as all that is necessaryfor them to react the lead sulphide is heat and then chemically they are in the proper condition to keep the charge well fluxed and in good smelting condition which is a prime essential. The ore should be larger than is usual for the reverbratory practice. While in the latter practice 4 or 5 mesh is the most advantageous in the open hearth process the ore should above pea size if possible nut and pea size mixed with the nut size predominating forms a good smelting mixture. Though fine ore is treated a small percentage being on the charge yet the loss due to the small particles being blown away is very great and while they are recovered in the Flue Fume yet it ties up so much lead and it is inevitable that a certain percentage of it should be lost in the handling and subsequent smelting of it that otherwise would be saved. The fine ore is thrown on the charge wet but before it can be turned under a good deal is blown away. When fine ore is to be treated and it can be arranged economically it should be agglomerated in the reverbratory furnace. In south west Missouri this has not been economically advisable and it has been smelted in the ore-hearth with the coarse galena. So much for the condition of the material for smelting we will now take up the smelting operation itself. Taking up first the mode of operation that gives the best results - using the American water jacketed ore-hearth or "eye".

One of the great bugbears in lead smelting and especially with the open hearth process is the large amount of lead converted into fume. And unless we can arrange to recover these lead values we will lack quite a little in making ends meet. In order for our smelting to be most economical we will use one of two methods for recovering the fume. Either a method of dry settling in a fume chamber or "Trail" system, or by passing the fumes through woolen bags and thus the lead fumes. Experience teaches that the following charge will about represent the ratios of galena smelted and fume caught.

6300	pounds	cleaned galena or "Mineral",
500	"	burned white fume
200	"	dry blue fume.
7000	"	total charge for four men.

the fume recovered is divided into two classes i,e, white and blue fume for reasons to be noted further on. The blue fume is recovered from that part of the fume chambers immediately adjoining the furnaces. The white fume consists of the remainder of the fume caught. The furnaces will be run until such time as the fume collected makes it not advisable,due to its filling up the chambers, to run longer. Then unless the system for collecting the fumes is duplicated, the furnaces will be closed down and the fume burned and cleaned out of the chambers. In order to ignite this fume which is now an impalpable bluish gray powder some coal oil is poured on it and a piece of waste or something of that nature saturated with coal oil set fire to and thrown on it. This is necessary in order to furnish enough heat to start the combustion.

The combustion after being started will proceed of itself the sulphur in the fume furnishing in its burning the requisite amount of heat, the carbon perhaps aiding to some extent. However the burning may slacken , when it does fresh oil is added and the combustion goes on afresh. This is repeated until the fume is entirely burned. It shrinks a good deal and burns into hard crusts very admirably adapted for smelting. The fume is then collected into two storage bins as previously mentioned for this reason. The fume collected just back of the eyes contains a good deal of fine material blown over from the ore-hearth including fine galena, lime pyrite , blende, charcoal etc. this material and the coarser fumes is kept so hot that when it is ready to be burned it is in such a state that it will not support combustion , and consequently it is pretty fine and in such a state physically that much lead can not be made from it. It is put in a bin to itself, water poured on it to enable the zinc present to exert its cementing powers. It carries about 1#13 per cent to 1.25 per cent zinc usually. When it is weighed to the smelters and allowance for moisture is ~~allowed~~ made, based on moisture determinations made from time to time. The white fume however will burn down into solid chunks or crusts of rather complex composition shown by the following analyses. Page 18.

<u>Analysis of blue fume</u>,

$PbSO_4$	22.74	per	cent.
PbO	3.79	"	"
PbS	51.59	"	"
SiO_2	2.76	"	"
Fe_2O_3	0.93	"	"
Al_2O_3	0.06	"	"
ZnS	5.57	"	"
ZnO	0.35	"	"
CaO	6.40	"	"
MgO	0.03	"	"
CO_2	3.83	"	"
SO_2	0.86	"	"

This gave on combustion 3.380 water and 14.41 % carbon dioxide.

A partial analysis of another sample gave,

Pb	51.86%	CaO	14.01%
ZnO	7.41%	MgO	0.16
Fe_2O_3	1.28	S	9.48
Al_2O_3	0.41	SO_3	5.10

Another sample taken of fume that looked as though it was already oxidized,

SiO_2	2.54%	Fe_2O_3	0.97%
PbS	10.41	Al_2O_3	0.05
$PbSO_4$	61.39	CaO	5.24
PbO	11.47	MgO	0.03
ZnS	0.11	CO_2	1.35
ZnO	0.42	SO_2	none

Yielding on combustion 7.38% carbon dioxide and 3.53 per cent water.

An average sample of the white fume before burning gave the following results. Dried at 100°C.

PbS	7.59%	CaO	0.07%
$PbSO_4$	44.83%	SiO_2	0.14
PbO	44.54	CO_2	0.19
Zn	0.50	SO_2	0.55
Fe_2O_3 & Al_2O_3	0.07		

On combustion yielding 3.18 carbon dioxide and 1.93% water.

This material after being burned or roasted gave the following composition, Dried at 100oC.

$PbSO_4$	48.76	per	cent.
PbO	46.82	"	"
Fe_2O_3	0.32	"	"
Al_2O_3	0.05	"	"
ZnO	0.27	"	"
CaO	0.48	"	"
SiO_2	0.10	"	"
CO_2	0.90	"	"
SO_2	1.65	"	"
H_2O	0.37	"	"
Total	99.72	"	"

As will be seen by the analysis this material does not contain any lead sulphide

sulphide. However in actual practice the white fume often has ~~some from~~ some unburned fume taken up with it though not very much.
This white fume when first collected is a bluish gray impalpable powder soft and unctuous to the touch and as stated before of a very complex n nature. Sulphur is present in all forms practically besides uncombined oxides, carbonic and silicic acids and some more or less complex hydrocarbons. This impalpable material could not be smelted were it not for the fact that on being burned it forms hard crusts nearly ideal for smelting.

The two sorts of fume are kept separate, with regard to the smelting practice , for two reasons,

1st. In order to have a uniform charge.

2nd. In order to charge it on the fire as desired.

In smelting galena there are times when the fire will take small quantities of blue fume and at other times it is a positive detriment hence being given to smelter separately he can charge it as his fire will handle it. The white fume is mixed with the galena and smelted, forming not only a flux but when hot acting on undecomposed galena and forming metallic lead.

All materials are weighed out to the smelter, each four men being given a charge of 7000 pounds of material. This is proportioned, of course, with regard to the kinds and amounts on hand. For an average charge see page 16. The 6300 pounds of cleaned galena are weighed out moist and contains perhaps two or two and a half per cent moisture. The coarse and the fine galena are weighed out separately when possible. So as to give every set of men the same porportionate charge. The men in the best practice are required to make a certain percentage of pig lead out of every material given them. Usually they are required to make 50% from the white fume, 40% from the blue fume, 70% from the cleaned galena. For all For all pig lead made over this required percentage the smelters are paid extra, ordinarily, a cent a pound, for failure to make their per cent they pay the company operating one cent per pound, however on an average they make from 25¢ to 50¢ extra per shift of 7000 pounds of mineral or galena to the man. This encourages a friendly rivalry among the men on the different furnaces and is productive of an increased yield of pig lead. At one place in southwest Missouri where such a system of rewards is in effect it has resulted in a crew of smelters superior to any other orehearth smelters anywhere, in their ability to make lead.

The method of starting up the furnaces is as follows:

Before the smelters come on in the morning a fire has been kindled in all of the lead pots by the night watchman usually, and also just before the men come on some of the fire is shoveled up on the apron so that when they come on the hot charcoal is burning freely. it is shoveled into the hearth the browse shoveled in more charcoal addad the blast is turned on and the fire starts to get hot pretty quick . Soon the metallic lead from the browse begins to trickle down, some more is reduced from the undecomposed compounds present, in the mean time the fire under the blast has grown very much hotter, some more charcoal and some fresh coarse galena has been added as well as some roasted white fume the lead begins to be reduced and so on, soon the fire is hot and in normal condition the lead in the basin has been ~~reduced~~ melted by the heat of the fire and the metallic lead trickling down upon it. The lead begins to o overflow into the lead pot and as soon as it is full the first two pigs are molded. The men work in pairs two working and two resting. A charge being 7000 pounds for four men. The man that works on the left side is called the front hand the one on the right side the back hand. The front hand has general charge of the furnace, he attends to the charging, addition of charcoal and lime, and regulates the blast, the back n hand assists the front hand spuds the fire and tends to the molding of the pig lead the back hand of the other pair skimming for him and vici versa He also keeps the fire under the lead pot.

The reactions between lead oxide, sulphate sulphide etc are the ones on which the smelting rests, they are expressed in the following equations.

$2\ PbS \quad 7O \quad PbO \quad PbSO_4 \quad SO_2$ (slow roasting)

$3\ PbS \quad 10\ O \quad 2\ PbO \quad PbSO_4 \quad 2\ SO_2$ (quick roasting)

Reactions of lead sulphide and lead oxide or sulphate,

(1) $PbS \quad 2\ PbO \quad 3Pb \quad SO_2$

(2) $PbS \quad 3\ PbO \quad 3\ Pb \quad PbO \quad SO_2$

(3) 2 PbS 2 PbO 3 Pb PbS SO_2

(4) PbS $PbSO_4$ 2 Pb 2 SO_2

(5) PbS 2 $PbSO_4$ Pb 2 PbO 3 SO_2

(6) PbS 3 $PbSO_4$ 4 PbO 4 SO_2

Lodin found that reaction (1) begins at 720°C. and (4) at 670°C. continuing up th 820°C. The show how the materials will probably act do to their proportions.

The mode of operating the eye is when the fire is in normal condition the front hand starts in and breaks up the fire clear across with his poker or bar. He does this by inserting his bar and thrusting it undef the charge in the lead bath, then using the front of the basin as a fulcrum he breaks up the charge. The back hand following with his shovel abd keeping the charge thrown up in the hearth. The front hand will p probablty raise the fire in perhaps a half dozen places beginning in the center usually and wbrking first to the right and th n to the to the left. The back hand then takes his spud or paddle and spuds the firet once on the right once in the middle and once on the left side. Quite a lityle art is gained in spudding by the back hands and a good one can be of great assistance in preventing lead losses. If the lead in the basin gets too hot he can lift the fire infront of each tuyere a moment each time and let the cold blast blow across the lead and thus cool it. The fire can be over spudded as well as under. The over spudding causes great lead losses. During this operation the front hand will ordinatily push the top of his fire back when it is lifted and let it fall under and mix. Sometimes however his fire demands other treatment and he gives it to it according to his best judgement. The charge in the hearth is then shoveled up and perhaps two shovels of the charge spread over the fire. two shovels of charcoal(or whatever it demands) are added the men wait a moment or two then the operation is repeated. This is kept up until enough lead is made to cast two pigs. When the other two men come on andrepeat the operattion until they have cast two pigs etc . In reality the first two smelt untill the lead pot is full, and then cast or mold two, then the second pair run until they have refilled the lead pot this is repeated until the wh whole charge is smelted when they burn down ~~its~~. after the fire is burned there still remains some material called browse it is the last of the charge what remains below the tuyeres it is skimmed off the basin and consists of particles of rich slag, rich dross, unaltered and more or less roasted galena, metallic lead etc. and is piled on the hearth covered with lime and used to start the furnaces next morning. It is pronounced as if spelled"bruise". The pigs weigh from 83 to 84 pounds e each, and are loaded on a car thirty at a time, weighed and shipped. Two pigs will be cast every ten to twenty minutes. From time to time when in the judgement of the front hand the fire will warrant it - the blue fume is charged and very often some dry bone or second class mineral is given th smelters and handled by them in the same way as the blue fume. The usual wage for both front and back hands is $1.75 per shift of 7000 pounds of mineral, they share equally in the extra which bringe their wages up to from $12 to $18 per week. The more lead recovered as pig lead the more they make. A charge can be smelted in from six to eight hours thus giving the smelters short hours and good wages. Often two consecutive shifts or charges are run, closing down the rest of the day. In this case the men begin in the morning at 6 A.M. and finish the first charge by from 12M. to 2 PM. when the second shift come on and finish usually from 8P.M. to 10 P.M. The second shift usually finishes in less time than the first for the reason that they begin with a hot basin. One man can wait on four eyes one shift. The slag made is about 5% of the charge, the fume about 8%. The slag carries from 37% to 42% lead and 8% to 11 or 12% zinc. The fume varies at the different smelters so much as well as the two kinds white and blue and depend s so much on the charavter of the charge that it is hard to give any general figures. Ihave never known it to fall below 66% lead while I have heard smelters claim to have 90% to 92% fume after burning. However this last I have never found to be true in my experience, and I don't expect to. The slag consists of more or less scorified oxides of zinc and lead, calcium, magnesium, iron etc. with undecomposed galena, blende, some metallic globules of lead held mechanically, particles of charcoal, lime etc. A sample of Lone Elm slag worked down for Mr. Kirby ran, 2352 grams submitted for assay

2352 grams submitted for assay,

Metallic lead picked out	307 grams	12.63%
Crushed roughly through 1/4 mesh		
600 gms. of this yielded	16.69 gms.	2.78%
150 gms. of this through # 20seive	5.968	3.97%
30 " " " " #60 "	0.065	2.17%
Total		21.55 Metallic lead.

No further removal of metallic lead was attempted, an alysis of the material showed,

$PbSO_4$ - - - - - - -	5.18 per cent
PbO - - - - - - -	33.55 " "
PbS - - - - - - -	14.75 " "
ZnO - - - - - - -	14.55 " "
ZnS - - - - - - -	3.64 " "
FeS_2 - - - - - - -	0.67 " "
Fe_2O_3 - - - - - - -	2.90 " "
Al_2O_3 - - - - - - -	0.78 " "
CaO - - - - - - -	11.49 " "
MgO - - - - - - -	0.12 " "
SiO_2 - - - - - - -	12.70 " "

This slag was formed from the smelting of mineral or galena carrying 73% or 74% lead consequently we would expect a slag like the above. When the mineral smelted assays 83% to 84% the slag runs about 38% to 42% lead and 8 to 11% or12% zinc. The average figure being about the mean. This slag is collected and smelted in the slag furnace described later in this paper.under the handling of by-products. The pig lead produced has about following percents of impurities.

As - - - - - -	0.00011%	Fe - - - - -	0.00686%
Sb - - - - - -	0.00146	Zn - - - - -	0.00035
Ag - - - - - -	0.00056		
Cu - - - - -	0.01782		
Bi - - - - -	none		
Cd - - - - -	none		
Ni - - - - -	0.00077		
Co - - - - -	0.00005		

The Pig Lead made from south west Missouri mineral or galena is a very soft lead and always commands the highest market price and will sell where other kinds will not. The by-products of the smelting operation are slag and fume.

The slag is always retreated in slag eye or low rectangular stack furnace usually about four feet high. A description of such a furnace is as follows. The bed plate supports the fire brick lining and extends over the lead pot. It slopes some toward the front from the back about an inch and a half to the foot. Before starting a bottom composed of equal parts of clay and coke is tamped on it five inches thick at the back and sloping down to an inch in thickness at the front. The lead pot is divided into two unequal compartments by a partition extending nearly to the bottom leaving a passage between the two compartments at the bottom. A cast Iron plate with an opening near the bottom comprises the front of the furnace. This opening is closed by ramming in a breast of clay around a wooden plug. The larger compartment of the lead pot is filled with charcoal. After the wooden plug is removed the "black slag" (i.e. the molten charge), runs through and over the larger compartment of the lead pot into a tank through which a slow stream of water flows. The lead filters through the charcoal in the larger compartment settles to the bottom and gradually rises in the smaller compartment from which it is molded from time to time. The furnace is inclosed in a hood with a short stack which carries off the fumes.

<u>The dimensions of the furnace are:</u>

Width of hearth - - - - - - -	26 inches.
Depth front to back - - - - - -	36 "
Height - - - - - - -	46 "
Diameter of tuyere - - - - - -	3 "
Height of tuyere above bed plate - - - -	10 "
Height of port - - - - - - -	9 "
Width " " - - - - - - -	12 "
Prolonged axis of tuyere strikes front lining of furnace above port - - - - - -	2 "
Slope of bed plate to the foot - - - -	1 1/2"
Size of bed plate - - - - - -	40 by48 "

Size of front plate - - - - - -	30 by 36 inches
Long diameter of lead pot - - - - -	36 "
Front to back oflead pot - - - - -	12 "
Depth of lead pot - - - - - -	12 "
Thickness of lining back and sides - - - -	9 "
Thickness of lining front - - - - - -	5 "

This furnace is very easily and simply blown in. First an ordinary wood fire is built on the bottom , next the furnace is filled with clean charcoal and a little blast is turned on. When the charcoal is burning well and ~~through~~ thoroughly, put on about a 6 inch bed or layer of coke and then turn on the full blast of 9 ounces. First charge clean slag not too large in size with the coke. In order to protect the furnace walls charge the slag around the sides and the coke in the center. After the full blast is on it will be about 45 minutes untill the charge is melted and enough been collected to start the black slag to flowing. The wooden plug is withdrawn and the slag begins to flow. It will be found necessary to change the charcoal in the lead pot every two or three hours, it takes about 16 hours smelting with a slightly acid slag to corrode the walls and form infusible masses on the bottom. The charging is then stopped and the furnace "blown out" by running off all the slag, tearing out the breast and drawing rest of charge and chilling with water. The furnace is then allowed to cool the rest of the day, when the infusible crusts are removed the furnace patched and it is then ready for another run. During the 16 hours about 30,000 to 37,000 pounds pounds of slag assaying 35% to 40% lead have been smelted giving 7500 pounds hard lead. It takes seven ~~five~~ men to run the slag eye ~~besides~~. A roustabout, four helpers and two furnace men ~~to~~ 480 pounds of charcoal and 4000 pounds of coke will also be needed. This does not include fuel to run boiler etc. This is one form of slag eye more modern furnaces are now being adopted. Particularly one used in the manufacture of Paint. It is run with ~~out~~ a hot blast in order to have as much volatilization as possible. In usual practice this is avoided. This furnace is 2 feet square and 6 feet high and stande on the ground. It has 11 tuyeres 7 of which ars placed just below the charging door the other four at the bottom. The tuyeres are 1 1/2 inches in diameter and pass through the water boxes. They are made straight purposely so ~~th~~ that a bar may be inserted to clear the opening. Over the futnace is a flue 4 1/2 feet wide by 7 feet high. The life of the furnace is from 15 to 20 days, when it is stopped for repairs. An average charge is,

2800	pounds	Scotch hearth slag
1000	"	white fume(burned)
600	"	Dry Bone
450	"	Blue fume

This gives a yield of 13 pigs or or 1100 pounds of dirty and impure lead which is remelted in what is termed a casting pot, poled with green wood and molded into pigs which after being trimmed are ready for the market.

Except when used in connection with paint manufacture the set of high tuyeres is not used there but on a level withe others Tendencies are more and more for a modern blast furnace scientifically operated for the smelting of slag etc.

The collection of fumes,

The other by-product, fume, is collected by one of two methods. Both illustrated very nicely in this district. Either by what might be termed the "trail" or fume chamber system ~~and~~ or by a filtering process - Both processes will be described.

1st. Filtering,

This process is exemplified at both Galena and Joplin. The fumes after leaving the ore hearth pass into a fume chamber(40 feet long by19 feet high and 6.5 feet wide) with a door in one side where the product can be removed. Here the coarse grained particles are removed. Often the fumes are first passed through a water cooled flue then into the fume chamber. They then pass through a sheet iron flue 5 feet in diameter to the fan and from it through a 4 foot flue to the fume chamber. The four foot flue being long enough to effect sufficient cooling to prevent damage to the bags. The bag house is a brick building, indeed all the material used on the inside is either brick or iron except the bags which are of unwashed wool. The building is 90 feet lone 50 feet wide and 45 feet high divided into two equal compartments by a partion wall running longitudinally . Through each compartment runs a ~~wall~~ floor 12 feet from the ground dividing the house into two stories. There are four rows of tie rods of ten each extending across the building between the sides. The supports for the first floor consist of iron pipes with plates at the ends and 12inches high. In each story there are twenty windows 6 by 2 feet, ten in each story. The windows in the bottom story are closed by ordinary sash, those in the top by iron doors so arranged that the fume can pass out but the rain can not come in. At the ridge of the roof there are more of such openings for the escape of the fume. In each room the ground floor is formed by the flat tops of two rows of sheet iron hoppersof the shape of a truncated pyramid. These hoppers are to collect the fume filtered out by the bags. They extend to within 3 1/2 feet of the ground Each one is supported on four iron pipes cased with refractory clay pipes The hoppers are closed at the bottom by a draw plate each row has ten hoppers and forms the flue. There being therefore four flues in the house. The flues with hopper bottoms are all made of 1/16 inch iron Above each hoppers there are sixteen holes in which there i a thimble 12 inches high and 18 ins. in diameter, projecting upward. On these thimbles the lower end of each bag is tied fast. The bags are made of unwashed wool for the reason that the grease in the bags protects them from the action fumes and thereby prolongs their lives. While a cotton bag is wasted away very quickly. When new they are 33 feet long and 60 i inches in circumference, changing after they have been used awhile to 50 inches in circumference and 35 feet long. The bags are tied with stout cord and suspended from the frame work above. There are 800 bags in the house, formerly costing $9.00 each. The four flues with the ten hoppers each extent longitudinally with the building and are connected with the fume chamber leading from the fan. The gases are forced out through the bags distending the bags by their pressure anl leaving the fumes behind. Apparently the separation is practically perfect at one smelting plant they claim to recover 102% of all lead given them to smelt.,, The escaping gases are moreor less colorless. Access can b be had at all times to the lower chamber for the purpose of removing or emptying the hoppers, The bags are shaken every two dayswhen the hoppers a are emptied. This fume after being removed from the hoppers is piled in heeps on the floor and set fire to by placing in it a burning piece of waste or other material saturated ~~it~~ with coal oil. This burning takes about a day. The crusts formed are then taken and either resmelted as a part of the charge for the ore-hearth or are smelted in the slag eye.

The "trail"or fume chamber system,

This system consists of a number of fume chambers and houses through which the fume is lead until the particles of fume are finally deposited. There should be at least 1000 lineal feet of trail system and then there will still be a loss of a per cent and a half to a per cent and three quarters. After leaving the ore hearth the fume will pass into a large chamber eight feet high at least, and as wide with hopper bottom and as long as the width of the eyes. Here as already described the blue fume will be caught next it will pass through a short passage intoanother fume chamber with partitions arranged as illustrated,

and so on through the different houses to the stack,from which it is thrown into the air. The stack is usually placed on a hill and still will need to be 40 tp 60 feet higher, im order to form a natural draft strong enough. at the base of the stack should be placed a large damper for regulating this draft. No fan is used in this process nature being called on to furnish the draft. In order to assist the natural settling of the fumes several mechanical precautions are observed.

The walls of the fume chambers are kept cool, it having been found that a cool surface attracts the particles of fume while a hot surface repels them. It is always well to cool the fumes as much as possible without loosing the natural draft. The introduction of cold air into the fume chambers has been tried as well as sugested, but experience teaches that it is not beneficial. As the objest sought is gaind better when the proportion of gases to fume is kept as low as possible. An expansion or air increase in the volume are a good deal different in their effect. An expansion lessens what might be termed the "buoyancy" and thus allows the fume to settle better especially when at the same time the velocity of the current is lessend. The dilution with other gases is analogous to the dilution of water carrying sediment in suspension, it makes it harder to effect its deposition. While the addition of cold air decreasesthe temperature without a doubt and is an advantage in this respect it does not admit of an expansion of the gases as can be seen from a theoretical handling of the subject, the air admitted when expanded to the resulting temperature being exactly the right volume to fill the space left by the contraction of the original volume of gases due to the lowering of the temperature. Hence the "buoyancy" is increased and the addition will prove a disadvantage.

Gases in fume chamber, Let the volume $= V = G = V'$ (new volume after admission)

" Abs. temperature $= T$

Gases admitted, Volume $= V_0 = G_0 = V'$ (dimensions chamber the same)

Abs. Temp. $= T_0$

as stated before the dimensions of the chamber at the point of admission are constant hence we have,

$V + V_1 = V' + V_1 = X =$ constant

Resulting temperature $= \dfrac{VT + V_0T_0}{V + V_0} = T'$

Expressed in terms of the temperatures,

Resulting volume of gases $G = V + \dfrac{(T' - T_0)V}{273} = V'$

Resulting volume of gases $G_0 = V_0 + \dfrac{(T' - T_0) V_0}{273} = V_1$

Then,

$$V' + V_1 = V + \frac{(T' - T)V}{273} + V_0 + \frac{(T' - T_0)V_1}{273}$$

$$= \frac{273 V + V(T' - T)}{273} + \frac{273V_0 + V_0(T' - T_0)}{273}$$

$$= \frac{273V + VT' - VT + 273 V_0 + V_0T - V_0T_0}{273}$$

But

$$T' = \frac{VT + V_0T_0}{V + V_0}$$

Then,

$$V' + V_0 = \frac{273V + 273V_0 - VT + V\left(\dfrac{VT + V_0T_0}{V + V_0}\right) + V_0\left(\dfrac{VT + V_0T_0}{V + V_0}\right) - V_0T_0}{273}$$

$$V' + V_{\bullet} = \frac{273\ (V + Vo)^2 - VT(V + Vo) + V(VT + VoTo) + Vo(VT + VoTo) - VoTo(V + Vo)}{273\ (V + Vo\ )}$$

$$= \frac{273(V + Vo)^2 - VT(V + Vo) + V^2T + VVoTo + VoVT + Vo^2To - VTo(V + Vo)}{273\ (\ V + Vo\ )}$$

$$V' + V_1 = \frac{273(V + Vo)^2 - VT(\cancel{V + Vo}) + VT\ (\cancel{V} + Vo) + VoTo(\cancel{V} + Vo) - VoTo(\cancel{V} + Vo)}{273\ (\ V + Vo\ )}$$

$$V' + V_1 = (\ V + V_0\ )$$

as was before steted the admitted quantity of cold air prevents the expected expansion when the gases are cooled therefore it will always be best to use what might be termed an external method of cooling as we wish the gases to expand and approach a vacuum as this would be the ideal settling condition, gases cold no velocity, and a vacuum present.

The settling is also porportional to the amount of surface exposed for friction. There is only one drawback to carrying this out to the end that is, that it so lessens the draft that beyond a certain point we either have to build a flue so high that the cost will make it nearly impracticable or we have to put in artificial ventilation or draft. This should be prevented as long as possible as it is just that much extra cost. So instead of using longitudinal plates in the chambers small wires have been tried and found to about solve the problem. These are suspended about seven or eight inches apart and are so arranged as to be mechanically shaken, usually also a transverse vertical partitions extending upward from the floor a short distance are used to prevent the fume being carried along with the draft after it is settled out. As with the sediment carried by rivers a sudden checking of the velocity deposits the material, so it is in this case, and this is aimed at inthe construction of the trail, but it is very much harder to be realized with in the case of gases than with water. Water sprays in the chambers have been tried but with lead fume and its subsequent treatment this is out of the question, and is not used now.

The main points to be kept in mind are, in the trail system to use dry condensation, cool the gases, retard the velocity as abruptly as possible, do not add dilutants, but decrease the density, or buoyancy. nearly all successful methods will be found to be based on one of these or more than one of these principles. The gases after they leave the ore-hearth are from 386° to 400-° Fahr. they <u>must</u> be cooled for good condensation by the trail system or in order to protect the bags by the filtering system. The gases leaving the stack should be reduced in temperature to twice that of the atmosphere on the outside. The results then are found to be satisfactory for the trail system. For cooling the gases the fumes are either passed through sheet iron or steel flues exposed to the air for a sufficient length to cool them and then let into a large room for the expansion mentioned. Or they are passed through chambers containing vertical or inclined small flues open at both ends to the air. Or sometimes both methods are used. The method of cooling by exposure to the air in a steel chamber seems to be the favored one in this district.

At Joplin the fume is charged on a slag eye having a hot top and as much as possible volatilized, passed through a hot flue then cooled passed through a fan and further cooled and then passed to a second bag house where it is again filtered out. It is now in a very finely divided condition, is an impalpable powder pure white in color and makes an excellent white paint for which it is sold. It has a good body and mixes well with oil and is of the following composition:

$PbSO_4$ - - -	65.46%	65.00%
PbO - - -	25.85	25.89
ZnO - - -	5.95	6.02
Fe_2O_3 - - -	0.03	0.03
CaO - - -	0.02	0.02
CO_2 - - -	1.53	2.00
SO_2 - - -	0.04	none
H_2O - - -	0.69	0.85
Insoluble - -	0.08	0.08
Totals	99.65	99.89

The second paint (fume or bag) house is not as large as the first one it being 40 feet by 90 feet by 45 feet high, having but three rows of hoppers with nine in a row with twenty bags above each hopper. As the bags hang each has 168 feet of of surface or a total of 88,704 sq. feet of filtering surface. for the 528 bags. This house has also two stories the first story being nine feet high. The second floor is supported on 2 1/2 inch tie rods 9 feet apart and running from side wall to side wall. The weight being taken on eighteen 3 1/3 inch posts of pipe in two rows of nine each running lengthways with the house. Cross pieces of 1 1/2 inch pipe are laid across the 2 1/2 inch pipe every 2 feet. There are 21 escape flues along the ridge of the roof each 18 inches in diameter. The roof is supported by iron trusses, there being four of them in all. Indeed everey thing in this as well as in any bag house should be made of either iron or brick, something not acted upon by the gases, Except the bags which are of unwashed wool. The fumes pass fromm the fan to the cooling cylinders and from them into a distributing box 30 feet long and 10 feet wide with a hopper shaped bottom and running along the end of the house, the three flues lead from this, the gases pass through the bags and out. These three flues are hung from the 1 1/2 inch pipe mentioned before, by iron straps every 12 inches. The bags are tied to the top rods.

In conclusion some figures based on the actual operation of the furnace will be presented. The different smelters are as a rule very reticent about giving these figures to the public, In my own experience I have a good many figures and calculations which I am unable to present in this thesis. Those given however will no doubt prove interesting.

The American water-jacketed ore-hearth,

A trial run made on some very high grade galena though rather fine in size for the best results on the ore-hearth.

Weight on galena before rejigging- --- 421,020 pounds Assaying 83.78% lead

Weight given to the smelters 413,900 " Assay(85.51% lead)
(2.50% water)

Loss in jigging withour reference to moisture 1.21%

Recovered in form of pig lead - - - 330,632 pounds

" " " " "Zinc tailings" - - 5,000 Approx.

" " " " Mineral Sludge - - 500 "

" " " " Extra fume equivalent to 4,173 pig lead

" " " " Slag(41.50% lead) 17,875 pounds

Freight charges on mineral 50¢ per M, unloading 3¢ per M

Cost handling jigging smelting and loading on cars,

Labor $ 1.78 per M of mineral smelted.

Charcoal used 1446 bushels, Lime 26.75 bushels, Cordwood for pot fires

2.9 cords. Slack to furnish steam, 54,400 pounds, Unloading same 2 1/2 cents per M. Incidentals office salaries etc 25¢ per M. These figures give the results necessary for an idea of the smelting operation, The freight rate to St. Louis on Pig lead was 13¢ per hundred. The mineral was purchased on an assay basis, 80% lead being taken at the base and 35¢ per point being the allowance for higher assay values. However as yet there is very little "Mineral" or galena purchased in this district on an assay basis.

The "Jumbo" furnace used in connection with paint manufacture,

Trial run on about 57,000 pounds of mineral.

57,324 pounds actually smelted, Assay value probably 68.00% lead.

Produced	Pig Lead a a - -	25,549 pounds
	Slag - - - - -	11,140 "
	Dust - - - - -	5,000 "
	Blue Powder - - -	15,690 "

The blue powder and slag were then charged into the slag eye and converted into paint etc.,

Produced,	Pig lead - - - -	8,798 pounds
	Poor slag - - -- -	4,030 "
	Paint - - -	-14,387 "

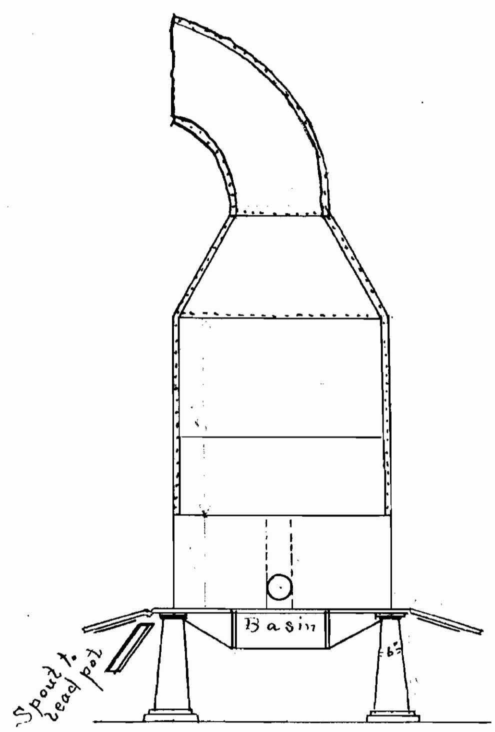
Cost statement,

Cost of mineral - - - -	$ 1169.38
Frgt. on white lead to east @ 45¢	64.52
Frgt on lead to E St.Louis @34¢	89.63
Commision 1%	12.51
Royalty to bag patents1/2 ¢ #...	71.68
Com. on white lead 2.5%	12.53
Cost of treatment - - - -	158.87
Total - - - - - -	$1579.11

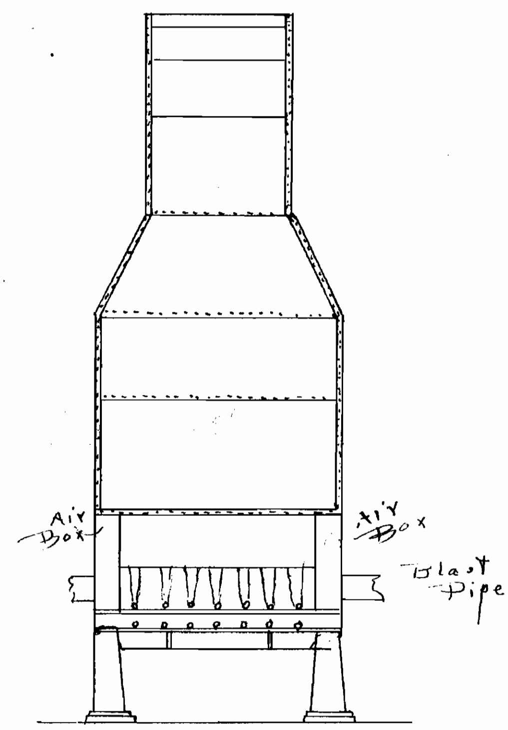
Pig lead sold @ 3.35 pr cwt. - - - -	$1251.12
White lead sold @ 3.50	501.79
Total - - - - - - -	$1752.91
Expenses as above - - - -	1579.11
Profit - - - - - - -	$ 173.80

These figures on the jumbo furnace are of former practice, having been unable to obtain figures of a recent date.

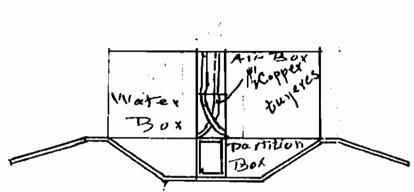
PLATE I.



Side elevation



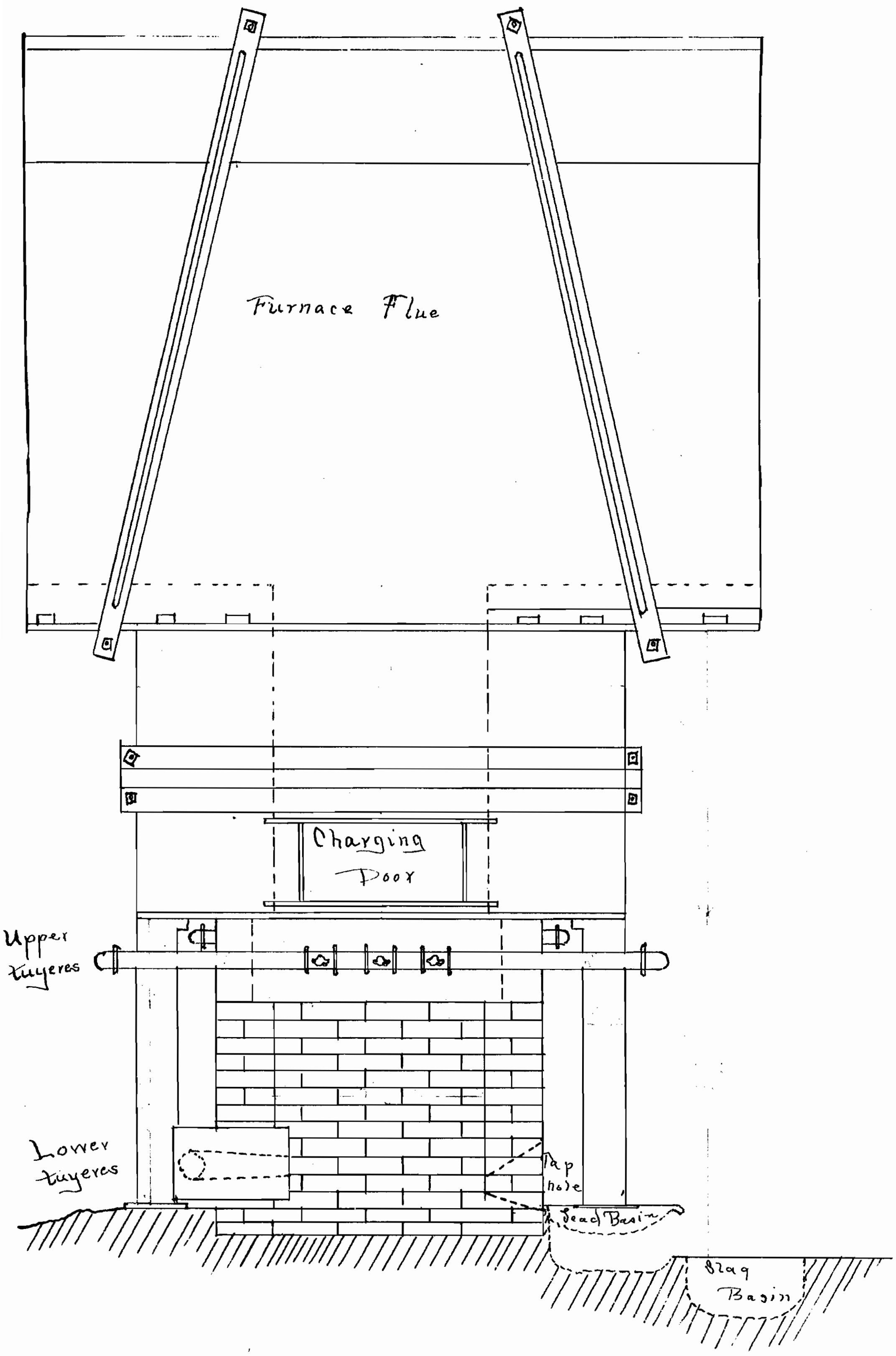
Front elevation



Section showing tuyeres.

<u>The</u> <u>Jumbo</u> <u>ore-hearth</u>.

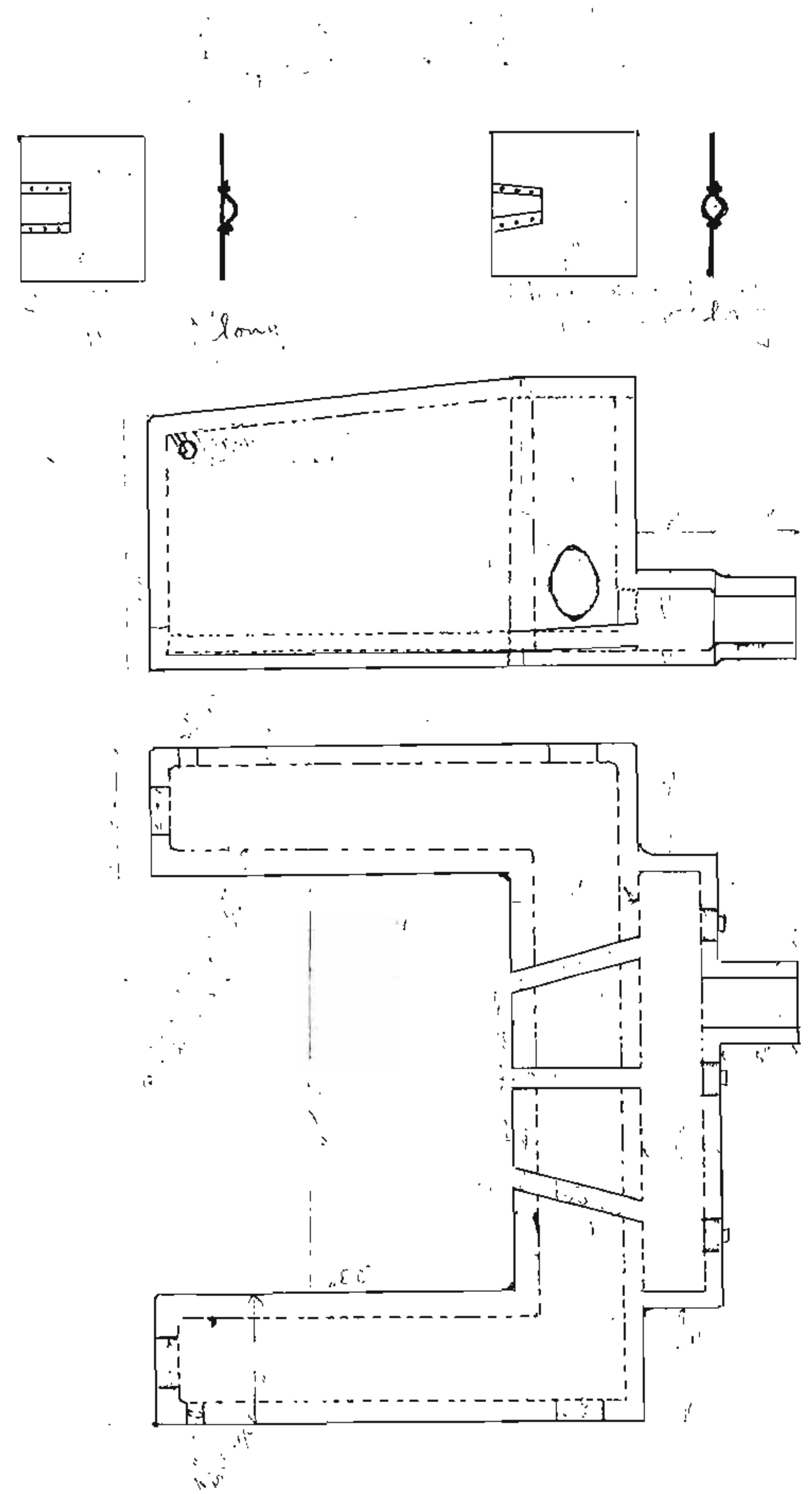
PLATE II.



Front elevation of Slag-eye.

Scale 1/2 inch to the foot.

Plate III.



Plan of jams or water jackets, the important part of an ore hearth furnace. Also the smelting and charging shovels made of Jessup saw steel.